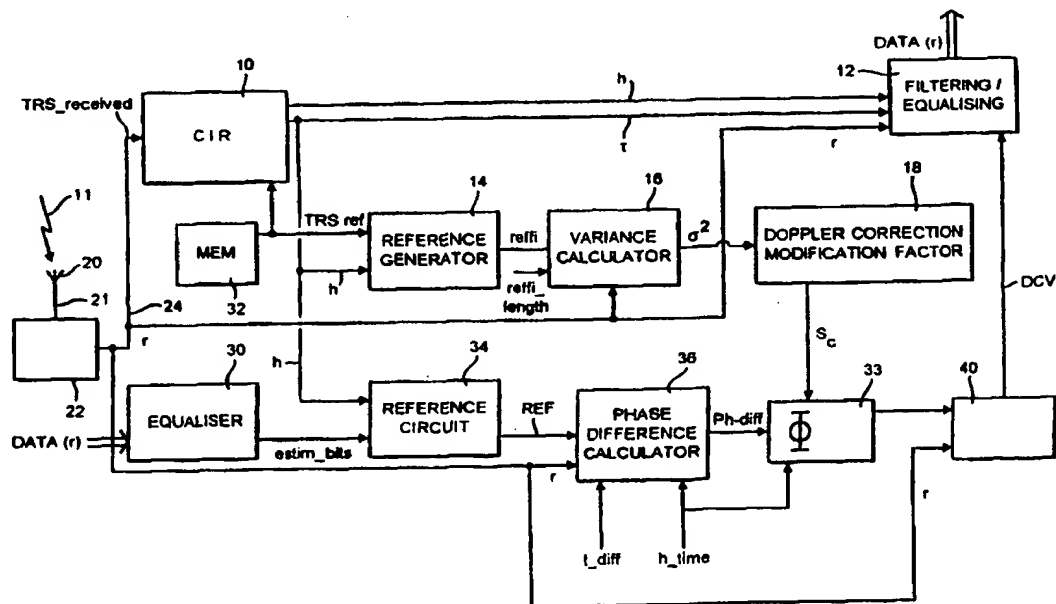




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(54) Title: COMPENSATION OF DOPPLER SHIFT IN A MOBILE COMMUNICATION SYSTEM



(57) Abstract

In a mobile communication system, signals which are transmitted from mobile stations moving relative to a base station are subject to a Doppler effect. A technique is described for compensating for that Doppler effect by using estimated bit decisions for received bits which are sufficiently close to a zero phase offset point so as not to have been corrupted by the Doppler effect. The Doppler shift measured using these estimated bits can then be applied to bits of the signal which are further away from the zero phase offset point.

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COMPENSATION OF DOPPLER SHIFT
IN A MOBILE COMMUNICATION SYSTEM.

The present invention relates to compensation of Doppler shift in a mobile communication station.

In a mobile communication system, signals which are transmitted from mobile stations moving relative to a base station are subject to the well-known Doppler effect, which causes a frequency shift in the frequency received at the base station relative to that which was transmitted by the mobile station. This frequency shift is referred to herein as the Doppler shift. The Doppler shift is dependent upon the speed and direction of movement of the mobile station relative to the base station. Thus, the Doppler effect can provide an increase or a decrease in the frequency, depending on the direction of movement of the mobile station relative to the base station. The magnitude of the Doppler shift is dependent on the speed with which the mobile station is moving relative to the base station.

Existing mobile communication installations provide a form of Doppler compensation, in that the frequency detection circuitry within the base station which selects a particular signal on a particular channel can take into account a certain amount of Doppler shift in the signal.

AU 664626 relates to a method and circuit arrangement for compensating for the Doppler shift in a radio signal propagating between a base station and a mobile station when the mobile station approaches and moves past the base station. As a mobile station approaches the base station with a decreasing propagating time delay, the propagating time delay is integrated at intervals to determine how the propagating time delay varies with time. This information is used to effect a change in the radio signal frequency at a particular time to compensate for the sudden Doppler shift as the mobile station moves past the base station. In a TDMA system, the interrogation occurs at intervals equal to

an integral number of time frames. In the GSM standard a time frame comprises eight consecutive time slots and a single transmission burst passes between a particular mobile station and base station in any one time frame.

Thus, in this method of Doppler compensation decisions are made in response to past and incoming signals to improve the reception at a future time, i.e. it is a reactive system. It would be desirable to implement a system which can actively compensate for Doppler shifts in an incoming signal in real time.

According to one aspect of the invention there is provided a method for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, the method comprising:

- determining a channel impulse response for the channel on which the signal is received;

- using the channel impulse response to estimate data bits of a selected portion of the received signal;

- generating a reference vector using the channel impulse response and the estimated data bits;

- determining a Doppler characteristic using the selected portion of the received signal and the reference vector; and

- using the Doppler characteristic to provide a Doppler shift compensation for the received signal.

According to another aspect of the invention there is provided a system for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, the system comprising:

- a channel impulse response determination circuit for determining a channel impulse response for the channel on which the signal is received;

- an estimation circuit connected to receive the received signal on the channel impulse response and to estimate data bits of a selected portion of the received signal using the channel impulse response;

a reference generator for generating a reference vector using the channel impulse response and the estimated data bits; circuitry for determining a Doppler characteristic using the selected portion of the received signal and the reference vector; and

a Doppler shift compensation circuit operable to use the Doppler characteristic to provide a Doppler shift compensation for the received signal.

The invention is particularly applicable in TDMA mobile communication systems where the signal comprises a transmission burst. The selected portion is located in the transmission burst close to a zero phase offset point so that the effect of the Doppler characteristic is sufficiently small that it does not corrupt the transmitted bits.

According to the GSM standard, a TDMA transmission burst comprises a training sequence which is normally used to determine the channel impulse response for the channel on which the signal is received. This is done by a convolution of the received training sequence with a stored version of the training sequence.

In existing systems, the channel impulse response is used to remove from the received signal the effects of the transmission channel on the signal, in particular multi-path and attenuation effects.

According to the GSM standard, the "cleaned up" and filtered signal is demodulated to remove the IQ modulation by means of which the data in the signal was transmitted. Then, the demodulated signal can be decoded to generate hard bits. This can be done by a Viterbi technique.

The Doppler shift is estimated from samples of the received signal. The estimate for Doppler shift is thus dependent on channel quality, and typically gets worse when the channel quality is poor and better as the channel quality improves. When

there is no Doppler shift and the channel conditions are near the sensitivity level of a receiver, the application of a Doppler compensation algorithm degrades the performance of the receiver.

On the other hand, if there is a Doppler shift in poor channel conditions near the sensitivity level of the receiver, the receiver is not able to meet the reference sensitivity limits if a Doppler compensation algorithm is implemented.

According to one embodiment of the present invention the method for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, includes:

- detecting the quality of the received signal; and
- implementing a Doppler shift compensation in dependence on the detected signal quality.

Thus in this embodiment Doppler shift compensation is used only or mainly in good enough channel conditions. This provides an increase in performance for the receiver. The technique is provided for ensuring that Doppler compensation does not degrade the sensitivity of the receiver.

The step of detecting signal quality can include estimating the noise energy component of the signal. This can either be used itself to generate a Doppler correction modification factor for controlling the Doppler shift compensation in dependence on the detected signal quality, or to generate a signal to noise ratio for the received signal, which would then be used to generate the Doppler correction modification factor.

The Doppler compensation can be implemented as any appropriate user defined function of signal quality. For example, it could be a linear function or a step function.

In the described embodiment, the adaptive method for Doppler correction applied to a GSM system first estimates the quality

of the channel and uses the resulting modification factor to scale a calculated phase difference between a reference signal and the actual received signal.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made by way of example to the accompanying drawings in which:

Figure 1 is a diagram of a signal burst in a mobile communication system;

Figure 2 is a block diagram of circuitry for implementing modified Doppler shift compensation; and

Figure 2a is a block diagram of a revised Doppler correction modification factor generator circuit.

Figure 1 illustrates a normal burst in a mobile communication system according to the GSM standard. This figure represents a burst received at a base station. For a TDMA system according to the GSM standard, mobile stations transmit bursts as modulated signals on frequency channels allocated by a base station controller. One frequency channel may support up to eight bursts, each burst associated with a respective call, where each call is allocated a time slot in which to send the burst. Further details of a TDMA system according to the GSM standard are not described herein because they are known to a person skilled in the art.

The normal burst contains two packets of 58 bits (DATA) surrounding a training sequence (TRS) of 26 bits. Three tail bits (TS) are added at each end of the normal burst. The training sequence (TRS) is a predetermined sequence of bits which is sent by the mobile station (MS) and is known at the base station controller (BSC). It is utilised at the base station controller to estimate the impulse response of the channel over which the burst is sent. The actual information which is transmitted is located in the data bits (DATA) of the burst.

As explained earlier, the environment through which a signal passes from a mobile station to a base station can vary considerably, depending, amongst other things, on the distance between the mobile station and the base station, and interference caused by buildings and other structures in the area. As a result, the signal strength and signal quality of the signal received at the base station varies widely. Moreover, for moving mobile stations, the signal received by the base station is subject to a Doppler shift which should be corrected.

The circuit described herein provide a Doppler shift correction. The particular circuit described in relation to Figure 2 provides a correction only in situations where the channel conditions are good enough to give adequate signal quality received at the base station. Thus, a modification factor S_c is generated dependent on signal quality, which is used to control the Doppler shift correction so that Doppler shift correction is applied only in good enough channel conditions. It should be appreciated that although the use of a modification factor S_c is advantageous it is not essential to implementing a Doppler correction per se.

Figure 2 illustrates a circuit 1 suitable for implementing a Doppler compensation in a GSM system. It should be understood that the various blocks in Figure 2, although illustrated as separate interconnected entities, do not necessarily represent separate physical entities, but are intended to represent diagrammatically the various steps which are carried out. The blocks could be implemented as circuits or a suitably programmed microprocessor may effect each of the functions which is individually assigned to the blocks.

An antenna 20 receives signals 11 from the mobile stations. The antenna 20 is connected, via an interconnect 21, to RF circuitry 22. This circuitry 22 operates on the received burst to downshift the frequency to the baseband frequency and to sample the burst to provide from the analogue signal digital sampled values. The output of RF circuitry 22 is a sampled burst r (in

digital form), sampled at the expected bit rate of the transmitted signal. Figure 1 illustrates such a burst. The output of circuitry 22 is supplied along line 24 to a channel impulse response (C.I.R.) block 10, to a variance calculator 16 to enable estimation of the quality of the communication channel (as described later), to filtering and equalisation circuitry 12, to a phase difference calculator 36 and to transforming circuitry 40 to enable the estimation and application of a Doppler shift correction to the burst r .

The top part of Figure 2 illustrates the circuitry required for implementing the adaptive part of the system, to generate the Doppler correction modification factor S_c . A memory 32 holds the training sequence TRSref which is the predetermined sequence of bits which is sent by the mobile station MS as a training sequence and received at the base station as TRS_received. The reference training sequence TRSref is supplied to a reference generator 14 and to the channel impulse response (C.I.R.) block 10. The reference generator 14 also receives the estimated channel impulse response h from the channel impulse response block 10.

The C.I.R. block 10 receives the burst r , including the received training sequence TRS_received and calculates an estimated channel impulse response h by calculating the cross correlation between the received training sequence TRSreceived and the known training sequence TRSref. So,

$$h = \text{xcorr} (\text{TRS_received}, \text{TRSref}) \quad (\text{equation 1})$$

It will be appreciated that, prior to effecting the cross correlation, the known training sequence TRSref, which is stored in digital form, is i, q modulated similarly to the manner in which the training sequence has been modulated at the MS for transmission, according to the GSM standard. The cross correlation is done in a known manner to produce a channel impulse response in the form of five tap values $(h(i))_{i=0 \text{ to } 4}$.

As is known, the estimated impulse response h is used to calculate the expected estimate of the data in the received burst, as though the data has been subject to the same average noise.

The C.I.R. block also generates timing advance information τ , which is used to determine where in the allocated time slot the received burst r is located.

For each burst, the estimated channel impulse response h for that burst is calculated by the CIR block 10 and is supplied to filtering/equalising circuitry which allows the data, $DATA(r)$, in that burst to be recovered. As is known, the filtering/equalising circuit 12 receives the channel impulse response h and timing information τ for the received burst to allow the signal to be demodulated, filtered and decoded, to recover the data in a known manner.

The reference generator 14 produces a reference vector, $reffi$, which is calculated using the convolution of the impulse response and the known training sequence. Thus, the reference generator 14 performs the following calculation:

$$reffi = h * TRSref \quad (\text{equation 2})$$

In more detail, (where $reffi_k$ represents the k th sample of the signal $reffi$)

$$reffi_k = \sum_{i=0}^{N-1} h_i \cdot (1 - 2 \cdot TRS_{k-i}) \quad (\text{equation 3})$$

in which N represents the number of tap values in the estimated impulse response h ($N = 5$ in the described embodiment), and k runs from $N-1$ to 25.

The vector $reffi$ is supplied from the reference generator to the

variance calculator 16. As described above, the variance calculator also receives the burst r , including the received training sequence. The variance calculator calculates a variance $\text{var} (\sigma^2)$ according to the following equation:

$$\text{var} = \frac{\sum_{k=4}^{25} (|r_k - \text{reff}_k|^2)}{\text{reff_length}} \quad (\text{equation 4})$$

The term reff_length is a constant representing the length of the reference signal, reff_i . This is calculated by multiplying the number of samples (22) by the bit separation.

In equation 4, the values of r_k are the sampled values of the received training sequence for the burst r .

It will be appreciated that each actual received sample r_k will have a noise level which is different to the averaged estimated noise level derived from the channel impulse response and reflected in the reference samples reff_k . Thus, the variance gives an indication of the level of noise energy actually received, and thus signal quality.

The output σ^2 of the variance calculator 16 is supplied to a Doppler correction modification factor circuit 18. The Doppler correction modification factor circuit 18 uses the calculated variance σ^2 to generate a modification factor S_c using a function which can be determined by a user. In the embodiment shown in Figure 2, the Doppler correction modification factor circuit generates the modification S_c as a function of the variance σ^2 , for example a linear function or a non-linear function such as a step function.

In another embodiment of the invention the value of S_c is calculated in dependence upon a signal to noise ratio (SNR) of the channel. Figure 2a illustrates circuitry for a Doppler

correction modification circuit 18' for implementing such an embodiment. A SNR calculator 42 receives the calculated variance σ^2 from the variance calculator 16 and an energy value E. The signal energy E may be determined from the calculated signal reffi in accordance with the following:

$$E = \sum_{k=4}^{25} \frac{|reffi_k|^2}{reffi_length} \quad (\text{equation 4a})$$

Alternatively the tap values can be used to derive the signal energy, E, of the channel according to the following:

$$E = \sum_{i=0}^4 (h(i))^2$$

The SNR value is calculated by the SNR calculator 42 in accordance with the following equation:

$$SNR = \frac{E}{\sigma^2} \quad (\text{equation 4b})$$

The above referenced technique is described in our earlier Application No. PCT/FI96/00461, the contents of which are herein incorporated by reference.

The SNR value is then supplied to a revised modification factor generating circuit 44. This circuit 44 calculates the value of the modification factor S_c as a function of the SNR value, for example a linear function or a non-linear function such as a step function.

The lower part of the circuit in Figure 2 illustrates in block diagram form a system for implementing a Doppler shift

correction. However, it will be apparent that the Doppler correction adaptive part described above could be used with other implementations of Doppler correction.

The main function of the adaptive part of the circuit described above is to provide a Doppler correction modification factor S_c which is based on the channel conditions, so that Doppler correction is used only or mainly in good enough channel conditions. This is useful in any type of Doppler correction. A particular Doppler correction circuit is discussed in the following.

An equalisation circuit 30, for example a Viterbi equaliser, receives the filtered, demodulated and equalised signal DATA(r) from the filtering and equalisation circuitry 12. The equalisation circuit 30 operates on a part of the data sequence DATA of the burst (that part having been derived from ESTIM.BLOCK in Figure 1) to estimate and output bits which were sent from the mobile station MS. This output is referred to herein as `estim_bits`, and they run from $k=j$ to $k=j+n$. The equalisation circuit 30 operates to make decisions of the bits as in known mobile communication systems and thus it will not be described further herein.

The estimated bit decisions `estim_bits` are supplied to a reference circuit 34. The reference circuit 34 generates a reference vector `ref` by using a convolution of the estimated bit decisions and the estimated impulse response h , according to the following equation:

$$\text{ref} = \text{estim_bits} * h \quad (\text{equation 5})$$

Thus, the reference vector `ref` comprises a set of samples ref_k ($k=j \rightarrow j+n$), each having real and imaginary values. The reference vector `ref` is supplied to a phase difference calculator 36. As described earlier, the phase difference calculator 36 also

receives the received burst r . As known in the art, the received burst comprises samples r_k each having real and imaginary values.

The phase difference calculator uses a value t_diff which represents the time between a zero phase offset point h_time and the middle of the estimation block, as illustrated in Figure 1. The zero phase offset point h_time is a zero phase offset point inside the training sequence where the calculated impulse response is true. In practice, this is typically the middle of the training sequence. The value of t_diff and h_time can be determined during the design phase of the system, and a constant thereafter. Of course, they could be reprogrammed if necessary during use of the system.

In addition, the location (j) of the beginning of the estimation block $estim_block$ and its length (n) is determined and programmed into the equalisation circuit 30. The estimation block is selected so that the Doppler offset has not yet corrupted the received bits.

The phase change per bit duration (ph_diff) resulting from the Doppler effect (the Doppler characteristic) is calculated from the reference signal ref and the actual received signal r by the phase difference calculator 36 according to one of the following equations:

$$ph_diff = \frac{1}{t_diff} \tan^{-1} \left\{ \frac{\sum_k \text{imag}(r_k \cdot ref^*_k)}{\sum_k \text{real}(r_k \cdot ref^*_k)} \right\} \quad (\text{equation 6})$$

$$ph_diff = \frac{1}{t_diff} \sum_k \cdot \tan^{-1} \left\{ \frac{\text{imag}(r_k \cdot ref^*_k)}{\text{real}(r_k \cdot ref^*_k)} \right\} / \text{length}(k) \quad (\text{equation 7})$$

where k runs from j to $j+n$, and where $\text{length}(k)$ represents the amount of different k values in the summation, i.e. n .

A Doppler correction circuit 38 is then used to correct the

estimated Doppler shift from the received samples. The Doppler correction circuit 38 receives the zero phase offset point h_time and the Doppler correction modification factor S_c . Furthermore, it receives the calculated phase difference from the phase difference calculator 36. Knowing that the point h_time has zero phase offset, the actual Doppler phase shift ϕ can be calculated for each bit as follows:

$$\phi_k = S_c \cdot ph_diff \cdot (k - h_time) \quad (\text{equation 8})$$

where k is a bit index of the received sample r . When the index $k < h_time$ the phase shift has an opposite sign to when $k > h_time$. It will be apparent that if the Doppler correction circuitry is operating in independence of the adaptive circuitry which produces S_c , S_c will default to 1 in equation 8.

Transforming circuitry 40 is then used to implement the Doppler shift correction on the received burst r to produce a corrected signal. The transforming circuitry receives the estimated Doppler shift vector ϕ (comprising the ϕ_k values) and sampled values of the received burst r . It performs a CORDIC operation to correct for the Doppler shift of each sample, according to the following operation.

$$\begin{pmatrix} N_real_sample(k) \\ N_imag_sample(k) \end{pmatrix} = \begin{pmatrix} \cos\phi_k & \sin\phi_k \\ \sin\phi_k & \cos\phi_k \end{pmatrix} \begin{pmatrix} real(r_k) \\ imag(r_k) \end{pmatrix} \quad (\text{equation 9})$$

The Doppler shift corrected vector DCV which is output from the transforming circuitry 40 is supplied to the filtering/equalising circuit 12, so that the Doppler corrected signal is used to recover the data from the signal.

As part of the Doppler correction technique described above, bit decisions for the estimation block have already been made. These constitute part of the data. It is thus not necessary to estimate the same bits again, although this could be done.

Instead, the equalisation circuit 30 can be stopped at the end of the estimation block and the current state preserved. Next, the Doppler correction is performed for the remaining bits and the Viterbi equalisation is then executed to the end of the time slot on the Doppler corrected bits. In the second part, the Doppler correction may be done to the first part of the time slot and the Viterbi estimation can then be performed for the data 58 in the first part of the time slot. This method reduces the required calculations in the receiver.

It is possible to implement a limit on the value of the phase difference ph_diff , so that if the phase difference is below a certain threshold, no correction is performed.

A typical environment where Doppler correction could be used is fast trains or motorways. In that situation, it is likely that there would be a line of sight path from the base station to the mobile station, so that the Doppler correction would be a constant value between different time slots if the velocity of the mobile station is the same. In that case, an average value of the phase difference could be calculated from several different time slots, and this average value could be used as a correction value.

In the case of a diversity receiver having a plurality of different branches, the phase differences can be calculated for all branches using the same estimates as the received samples, with each branch using its own impulse response.

CLAIMS:

1. A method for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, the method comprising:

determining a channel impulse response for the channel on which the signal is received;

using the channel impulse response to estimate data bits of a selected portion of the received signal;

generating a reference vector using the channel impulse response and the estimated data bits;

determining a Doppler characteristic using the selected portion of the received signal and the reference vector; and

using the Doppler characteristic to provide a Doppler shift compensation for the received signal.

2. A method according to claim 1, wherein the signal comprises a transmission burst in a TDMA mobile communication system.

3. A method according to claim 1, wherein the selected portion is located in said transmission burst close to a zero phase offset point, whereby it has been substantially unaffected by the Doppler characteristic.

4. A method according to claim 2 or 3, wherein the channel impulse response is determined from a training sequence in said transmission burst.

5. A method according to claim 1, 2, 3 or 4, wherein the data bits are estimated by:

using the channel impulse response to remove from the received signal the effects of the transmission channel for the signal;

demodulating the resulting signal; and

decoding the selected portion of the demodulated signal to estimate data bits.

6. A method according to claim 5, wherein the decoding step is done by a Viterbi method.

7. A method according to any preceding claim, wherein the step of using the Doppler characteristic comprises determining for each of a plurality of indexed samples of the received signal the Doppler phase shift for that sample based on the Doppler characteristic and the location of the induced sample within the received signal.

8. A method according to claim 7, where the samples are indexed at the bit rate of the received signal.

9. A system for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, the system comprising:

- a channel impulse response determination circuit for determining a channel impulse response for the channel on which the signal is received;

- an estimation circuit connected to receive the received signal on the channel impulse response and to estimate data bits of a selected portion of the received signal using the channel impulse response;

- a reference generator for generating a reference vector using the channel impulse response and the estimated data bits;

- circuitry for determining a Doppler characteristic using the selected portion of the received signal and the reference vector; and

- a Doppler shift compensation circuit operable to use the Doppler characteristic to provide a Doppler shift compensation for the received signal.

10. A system according to claim 9, wherein the estimation circuit comprises filtering an equalisation circuit operable to remove from the received signal the effects of the transmission channel for the signal by using the channel impulse response;

- demodulation circuitry for demodulating the resulting

signal; and

decoding circuitry for decoding the selected portion of the demodulated signal to estimate the data bits.

11. A system according to claim 10, wherein the decoding circuitry is a Viterbi decoder.

AMENDED CLAIMS

[received by the International Bureau on 3 March 1998 (3.03.98);
original claims 1,2,3,9 and 10 amended; remaining
claims unchanged (3 pages)]

1. A method for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, said signal comprising a sequence of transmission bursts, the method comprising:

determining for each transmission burst a channel impulse response for the channel on which the signal is received;

using the channel impulse response to estimate data bits of a selected portion of the transmission burst; said selected portion being located in said transmission burst close to a zero phase offset point;

generating a reference vector using the channel impulse response and the estimated data bits;

determining a Doppler characteristic in the form of a phase shift per bit duration using the selected portion of the received signal and the reference vector; and

using the Doppler characteristic determined for the selected portion to provide a Doppler shift compensation for the transmission burst.

2. A method according to claim 1, when used in a TDMA mobile communication system.

3. A method according to claim 1, wherein the Doppler shift compensation ϕ_k for each bit is calculated as follows, wherein k is the bit index, h_time is the point of zero phase offset and ph_diff is the phase shift per bit duration,

$$ph_diff \cdot (k - h_time).$$

4. A method according to claim 2 or 3, wherein the channel impulse response is determined from a training sequence in said transmission burst.

5. A method according to claim 1, 2, 3 or 4, wherein the data bits are estimated by:

AMENDED SHEET (ARTICLE 19)

using the channel impulse response to remove from the received signal the effects of the transmission channel for the signal;

demodulating the resulting signal; and

decoding the selected portion of the demodulated signal to estimate data bits.

6. A method according to claim 5, wherein the decoding step is done by a Viterbi method.

7. A method according to any preceding claim, wherein the step of using the Doppler characteristic comprises determining for each of a plurality of indexed samples of the received signal the Doppler phase shift for that sample based on the Doppler characteristic and the location of the induced sample within the received signal.

8. A method according to claim 7, where the samples are indexed at the bit rate of the received signal.

9. A system for compensating for Doppler shift in a signal transmitted between a mobile station and a base station in a mobile communication system, said signal comprising a sequence of transmission bursts, the system comprising:

a channel impulse response determination circuit for determining for each transmission burst a channel impulse response for the channel on which the signal is received;

an estimation circuit connected to receive the received signal on the channel impulse response and to estimate data bits of a selected portion of the transmitted burst using the channel impulse response, said selected portion being located in said transmission burst close to a zero phase offset point;

a reference generator for generating a reference vector using the channel impulse response and the estimated data bits;

circuitry for determining a Doppler characteristic in the form of a phase change per bit duration using the selected portion of the received signal and the reference vector; and

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a Doppler shift compensation circuit operable to use the Doppler characteristic to provide a Doppler shift compensation for the transmission burst.

10. A system according to claim 9, wherein the estimation circuit comprises:

filtering and equalisation circuitry operable to remove from the received signal the effects of the transmission channel for the signal by using the channel impulse response;

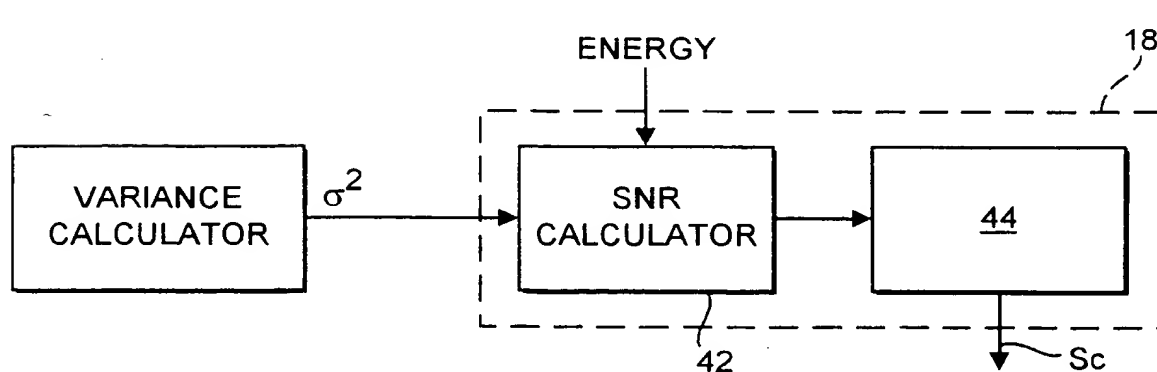
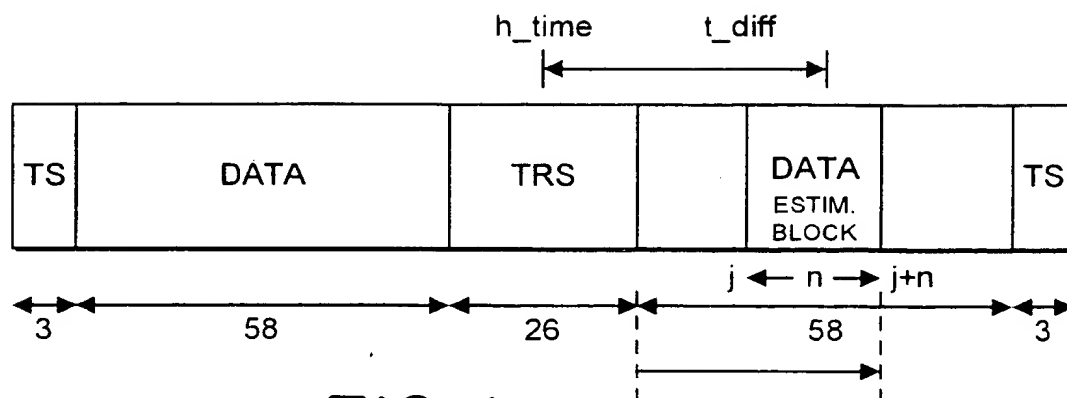
demodulation circuitry for demodulating the resulting signal; and

decoding circuitry for decoding the selected portion of the demodulated signal to estimate the data bits.

11. A system according to claim 10, wherein the decoding circuitry is a Viterbi decoder.

AMENDED SHEET (ARTICLE 19)

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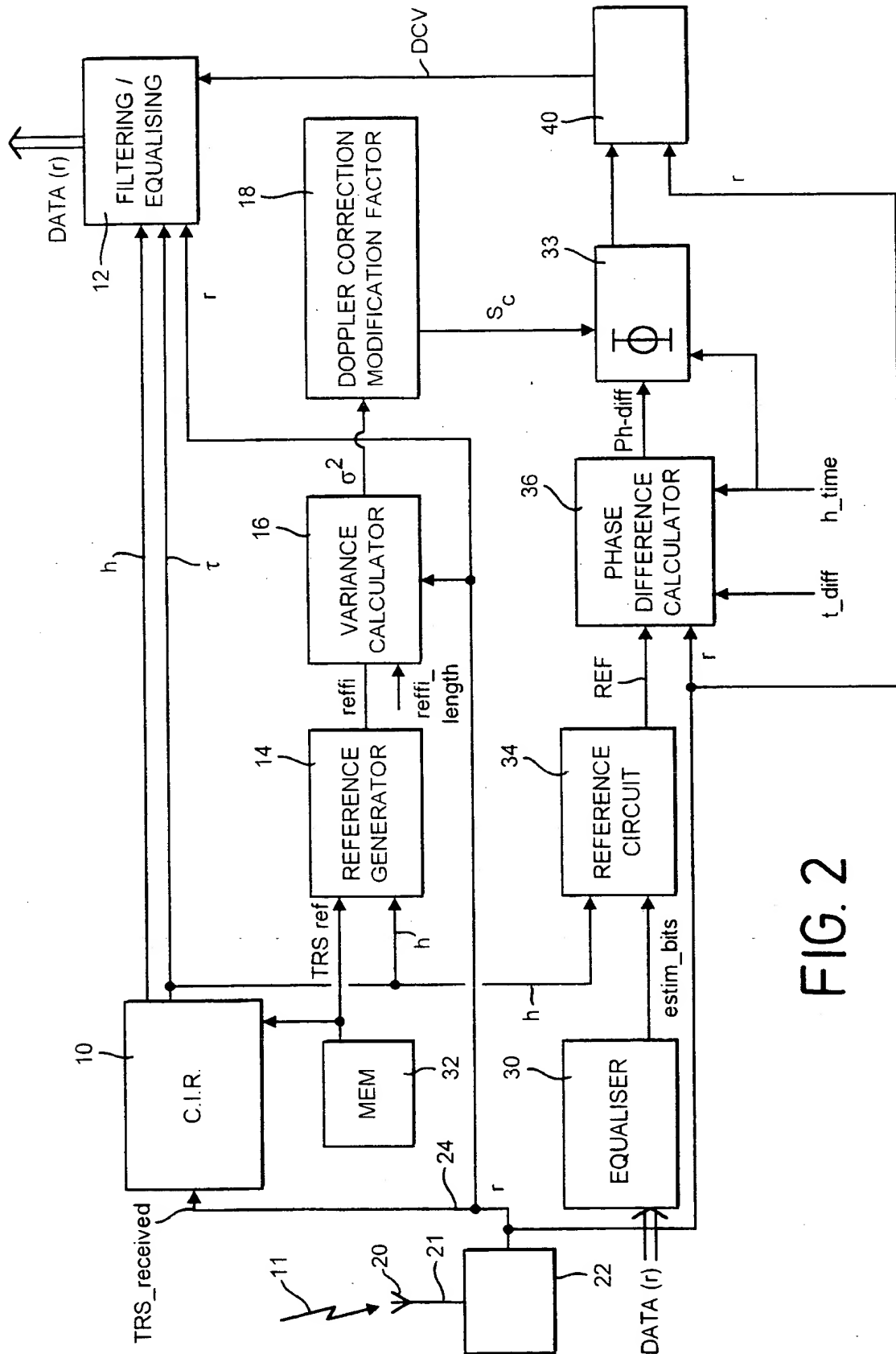


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 97/00488

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 731 587 A (AT&T) 11 September 1996 see column 3, line 1 - line 16 see column 5, line 40 - column 6, line 17 see column 8, line 26 - line 42 see column 9, line 15 - column 10, line 11 ---	1-6,9-11
A	EP 0 534 399 A (AEG MOBILE COMMUNICATION) 31 March 1993 see page 2, line 35 - line 54 see page 5, line 1 - line 4 -----	1,2,6,9, 11

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
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- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

21 October 1997

Date of mailing of the international search report

03.11.97

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 97/00488

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 731587 A	11-09-96	JP 8321854 A	03-12-96
EP 534399 A	31-03-93	DE 4132200 A	01-04-93
		DE 59207709 D	30-01-97